

Guidelines for Bridge Construction or Maintenance to Accommodate Fish & Wildlife Movement and Passage

Arizona Game and Fish Department, Habitat Branch

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Introduction/Background [\(top\)](#)

This document is intended as a general guideline to assist in the design, planning, placement, maintenance, or repair of bridges to minimize impacts to fish and wildlife passage/movement and habitat for bats.

Recent dramatic increases in urban, highway, and road development have increased interactions with wildlife and led to fragmented habitat. Each year in the United States more than 200 motorists are killed and thousands more are injured in animal-vehicle collisions. Billions of animals are injured or killed while property damage is measured in the millions. The inadequate size, poor design, poor placement, and insufficient availability of bridges result in limited use or avoidance of these structure by wildlife and fish. Since hydrological structures may not be adequate, crossing structures developed specifically for wildlife passage are now being incorporated into roadway designs. Projects currently in the planning stages are now being developed to provide for drainage as well as fish passage and wildlife movement. Employing multiple-use designs allows planners to proactively employ comprehensive strategies that incorporate watershed integrity, habitat connectivity, and provide cost savings by decreasing collisions, injuries to humans, and damage to vehicles.

Riparian areas are ecosystems associated with bodies of water such as streams, lakes, and wetlands; or communities which are dependent on the existence of perennial or ephemeral surface or subsurface water drainage. Although riparian areas are limited in the southwest, they possess a disproportionate importance and biological value. Perennial streams constitute less than 1% of the total land area of the state. From high-elevation montane meadows to low desert tinajas, Arizona contains a wide range of riparian ecosystems. Riparian areas also contain a rich and diverse assemblage of plant and animal species in comparison to adjacent upland areas. It

Bridges (cont.)

has been estimated that 75% or more of Arizona's wildlife species depend on riparian communities during some portion of their life cycle.

Bridges are designed with the principal objective of transporting water under roadways or passing one roadway over another. Less consideration is given to ecosystem processes such as hydrology, sediment transport, stream geomorphology, fish and wildlife passage, or wildlife habitat. Bridges may result in direct loss or fragmentation of habitat, and increase the disruption of ecosystem processes. Changes in hydrology as a result of bridged crossings can alter dimension, pattern, or profile of stream geomorphology. They have the potential to cause significant changes to stream morphology for considerable distances both above and below the bridge. Negative habitat impacts may also occur as a result of intermittent bridge maintenance. Impacts to movement corridors for fish and wildlife are most acute and have long-term impacts.

General Recommendations [\(top\)](#)

When planning bridge construction, consider designs that minimize impacts to fish and wildlife:

- Identify species in the area such as threatened, endangered, or any Species of Concern as defined by state or federal agencies, paying attention to those with special needs.
- Establish baseline data by monitoring fish and wildlife movements in the area in order to determine major crossing areas, behaviors, and crossing frequencies. This step is essential in designing a usable crossing structure.
- Minimize the number of times the road crosses a waterway, and avoid species known to be in the area, where practical.
- Identify structure shape and size needs for the species in the area; consider noise, temperature, light, and moisture requirements of the various species potentially utilizing the structure.
- Bridges should be designed to maintain the dimension, pattern, and profile of the stream geomorphology, minimizing negative impacts to that morphology.
- Construct bridges that accommodate upstream fish movement, provide for wildlife movements, and are wide enough to maintain consistent flow within the stream (i.e. bottom surface of structure should be flush with grade, no drop-offs or plunge pools, and no constriction of channel).
- Monitor and maintain bridges to ensure proper functionality while documenting use of the structure as habitat by bats.

Each project will have unique construction requirements, channel and floodplain geomorphology, hydrology, and associated biotic communities. As a result, we suggest that managers consider a broad range of potential impacts during project planning and when developing biological assessments and environmental impact statements. We recommend that transportation planners and design engineers work with interdisciplinary teams (biologists, hydrologists, ecologists) to develop a list of the potential physical, chemical, and biological components impacted by bridge construction and describe how impacts to these components could influence wildlife, their habitat, and movement corridors over space and time.

Bridges (cont.)

New bridge construction also provides the opportunity for design considerations that will benefit fish and wildlife resources. Bats are of primary importance due to the benefits they provide to the ecosystem and their current decline in numbers and distribution. Bridges can be designed to provide suitable day and night roosting habitat for different species of bats. Structural habitat requirements of bats differ by species and will vary across the state. The Arizona Game and Fish Department (Department) may be able to provide help in determining which species may be present in the area of a proposed bridge.

Design and construction of new bridges have the potential to affect movement of fish and wildlife along established movement corridors. Many animals use ephemeral washes, riparian corridors, and perennial streams for daily and seasonal migrations. Identification of existing species using specific corridors is necessary to accommodate their movement requirements. Where possible, the Department may request consideration be given to allowing for fish passage in a perennial or intermittent stream or may request that a fish barrier be considered instead. Recommendations on whether a fish passage or fish barrier is desired could be provided by the Department during the early scoping process.

General Bridge Structure Design [\(Top\)](#)

In general, bridge size depends on:

- 1) Area of drainage upstream from bridge (i.e. larger drainage areas will likely require larger bridge spans)
 - 2) Volume and flow of peak run-off
 - 3) Average stream width, depth, and gradient (slope) at the crossing site
 - 4) Amount of debris loading or scouring
 - 5) Size and species of animals/fish expected to utilize the bridge for passage
- Bridge design and materials should not degrade water quality or repel animals and fish. Therefore when constructing, make sure that materials used within the stream are clean, not prone to erosion, and non-toxic to aquatic life.
 - Bridges should be long enough to exceed the floodplain width, allowing flood flows expand onto the floodplain to minimize scour, erosion, and flooding.

Bridge design elements essential for successful fish and wildlife use include:

- 1) Suitable Habitat (suitable habitat should occur at both ends)
- 2) Appropriate Size
- 3) Placement Near or Within Natural Movement Corridors (if known)
- 4) Minimal Human Activity
- 5) Funneling/Fencing
- 6) Wildlife Accessibility
- 7) Ongoing Maintenance and Monitoring
- 8) Natural Substrate
- 9) Lighting

Bridges (cont.)

- Wide underpasses allow animals to have a broad viewing area which makes them feel less vulnerable.
- Give preference to bridge locations where streambed and banks are composed of firm, cohesive soils to minimize erosion.
- Maintain a natural substrate underneath the bridge. If concrete is necessary to prevent scour, then it is recommended to cover the concrete with a natural substrate.
- To facilitate both aquatic and terrestrial wildlife passage, bridges should be wide enough to span the stream to allow for some dry ground or an artificial ledge beneath the bridge on one or both sides.
- Rip Rap is difficult for ungulates and amphibians to traverse and should not be placed in front of or on the slopes adjacent to a passageway. If rip rap is required, then it should be buried, back-filled with topsoil, and planted with native vegetation.

Placement of Structure:

- Placement of bridges should be near or within natural wildlife movement corridors.
- Wildlife movement corridors often follow natural drainages and waterways.
- Use fencing to direct animals toward bridges and away from road approaches.
- Fencing should be tied into edges of bridges with no gaps.
- Bridged crossings on divided highways should be in a straight line to provide unobstructed views.

Construction Considerations:

- Construct during periods of low flow to minimize impacts to fish and wildlife and their habitat.
- During construction, minimize disturbance to the length of the natural stream channel and the natural flow of the water.
- Remove temporary fills and structures when construction is complete.

Fencing:

Fencing is crucial to the success of a bridge as a wildlife passage because it guides/funnels animals to use the structure and minimizes road crossings and wildlife mortality.

- To prevent animals from digging under fences (e.g. coyotes and deer); bury fences to a depth appropriate for the type of species in the area. See recommendations for [large](#), [medium](#), and [small](#) mammals, and [amphibians and reptiles](#) below.
- Minimize “natural ladders” adjacent to the fence which could facilitate an animal climbing over the fence (e.g. trees, large bushes, etc.).
- Fencing should extend on either side of the structure the entire length of the parcel boundary or just beyond a natural break in an animal’s ability to traverse the landscape and guide them to the bridge.
- Fencing should be tied into edges of bridges with no gaps.
- Escape ramps should be constructed when extensive fencing is utilized on one or both sides of a bridge to prevent animals from being trapped on the road.
- Appropriate types and sizes of fencing should be selected based on species in the area

Bridges (cont.)

Openness Ratio:

Appropriate bridge opening size is determined by the size of animals using the structure and the width of the road using the bridge. For example, as bridge width increases, the cross-sectional area of the opening must also increase. You can determine if your opening size is suitable by calculating the 'openness ratio' of the bridge opening, whereby:

$$\text{Openness Ratio} = (\text{bridge height} \times \text{bridge width}) / \text{bridge length}$$

Example: The minimum openness ratio required for large mammals is 0.75 (see [Large Mammals](#) below for further details). If bridge dimensions are 15 feet high by 15 feet wide by 60 feet long, the openness ratio is 3.75; the bridge is probably suitable for large mammal crossings. Keep in mind that this is a rule of thumb and one size does not fit all; certain species need much larger openings before they will pass.

- * **Below are some general recommendations for the sizes of bridge openings suitable for fish and wildlife. Keep in mind that the most suitable design will differ depending on the species that require passage.**

Large Mammals ([top](#))

This group includes species such as mountain lions, deer, bears, coyotes, wolf, elk, and bobcat. Large mammals generally stand at least 1.5 ft at the shoulder, and have a length of at least 2 ft (not including tail). As suggested by many studies, large mammals typically prefer large, open crossing structures, such as bridge underpasses and box culverts.

To be conducive for use by large mammals, bridges must:

- Be at least 6 feet high and likely larger depending on the species.
- Have an openness ratio of at least 0.75, but preferably 0.9.
- Be easily accessible.
- Have a fence height of approximately 8 feet to prevent large animals from jumping or climbing over. In addition, studies recommend chain link or woven wire fencing for large mammals.

Studies indicate that an open field of view must exist in order for large mammals to use a bridge crossing. A large mammal is more likely to pass under a bridge if suitable habitat is clearly visible on the other side. The need for an open field of view also correlates with the preference for a large openness ratio.

Structural Dimensions:

Data indicates preferences for structures that are taller in height, shorter in length, with larger cross-sectional areas and openness ratios. In general, the cross-sectional area of the structure entrance should become larger as the length of the structure increases to maintain a minimum openness ratio of 0.75. For a typical two-lane road (approximately 30 ft wide), the cross-sectional area of the structure opening should be 22 sq ft to accommodate a large mammal. For a typical four-lane road (approximately 60 ft wide), the cross-sectional area of the structure

Bridges (cont.)

opening should be 45 sq ft. For a road with six or more lanes (75 ft or wider), the cross-sectional area of the structure opening should be 60 sq ft.

Locating bridges near natural travel corridors is crucial to successful use of these structures by wildlife. For carnivores, this means placing the structures close to stream corridors or drainages, as these areas are frequented by prey and are commonly used by carnivores for travel. Wolves and bears are more likely to use bridges where there is no sign of human activity nearby. Distance from humans is the most important consideration in designing crossing structures for large carnivores. For ungulates, ensure there is a clear view of the structure's entrance and exit with no overhead ledges.

Medium Mammals ([top](#))

This group includes species such as javelina, opossum, skunk, raccoon, fox, and rabbit. Medium mammals generally range in height between 6 inches to 1.5 ft at the shoulder, and range from 16 inches to 2 ft in length.

To be conducive to use by medium sized mammals, bridges must:

- Be at least 3 feet high depending on the species.
- Have an openness ratio of at least 0.4.
- Be easily accessible.
- Have natural vegetation surrounding the approach and entrances.
- Have a fence height of approximately 3-6 ft to prevent medium mammals from jumping or climbing over. A fence material such as chain link is suggested.

Structural Dimensions:

Medium mammal preferences are generally for structures that are taller in height, shorter in length, with larger cross-sectional areas. The cross-sectional area of the structure entrance should become larger as the length of the structure increases to maintain a minimum openness ratio of 0.4. For a typical two-lane road (approximately 30 ft wide), the cross-sectional area of the structure opening should be 12 sq ft to accommodate a medium mammal. For a typical four-lane road (approximately 60 ft wide), the cross-sectional area of the structure opening should be 24 sq ft. For a road with six or more lanes (75 ft or wider), the cross-sectional area of the structure opening should be 30 sq ft.

Small Mammals ([top](#))

This group includes species such as squirrels, prairie dogs, rats, voles, and mice. Small mammals are generally a few inches high and up to 16 inches long.

To be conducive to use by small mammals, bridges must:

- Be at least 1 foot high, depending on the species.
- Provide low stature natural vegetation surrounding the approach and entrances.
- Be easily accessible.

Bridges (cont.)

- Have a fence height of at least 3-4 feet to prevent small animals from jumping or climbing over. Studies recommend impenetrable mesh as the most appropriate fencing material for small mammals.

Interior Cover:

Small mammals usually prefer some type of low cover in the bottom of the structure to function as protection from predators. Typically, small mammals will pass through a structure along the interior wall because it may feel more protected. Vegetation or other naturally occurring substrate, such as tree stumps, hollow logs, or rocks, will provide small animals with cover from predators, encouraging them to pass through a structure.

Bats ([top](#))

The Department recommends that project coordinators consider design elements that allow the use of bridges by bats because such structures have been identified as suitable habitat. Bats use bridges for both day roosting and night roosting. Day roosts protect bats from predators and buffer weather changes while resting and rearing their young. Night roosts are where bats gather to digest food in between nightly feeding bouts.

To be conducive for use by bats as day roosts, bridges should:

- Be greater than 10 feet above the ground.
- Have vertical crevices 0.5 to 1.25 inches wide.
- Have vertical crevices 12 inches or greater in depth.
- Be sealed from rainwater and debris from entering from above.
- Have full sun exposure of the structure.
- Not be situated over busy roadways passing underneath the structure.

Night roosts are used mostly between 10 p.m. and midnight, but some are used throughout the night for periodic rest between feeding. Bats are attracted to bridges that:

- Have a large thermal mass that remains warm at night.
- Are constructed of pre-stressed concrete girder spans, cast in place spans, or steel I-beams.
- Have vertical concrete surfaces located between beams that provide protection from wind and remain warm at night.

Existing bridges may have already been colonized by one or more species of bats. Bat surveys should be conducted prior to any maintenance work. In addition, bat surveys should be scheduled far in advance of proposed work to allow for schedule modification to avoid maternity roosts during the breeding season. Additionally, re-paving and other bridge maintenance activity have the potential to disturb or kill roosting bats. During bridge maintenance, roost habitat improvements and expansions could also be considered, allowing for increased bat populations. Underpasses, overpasses, and other bridges built for highway traffic also have the potential to provide suitable habitat for bats.

Refer to the Bat Conservation International (BCI) handbook (Bats in American Bridges) for additional specific information regarding bat use of bridges.

Bridges (cont.)

Amphibians & Reptiles [\(top\)](#)

This group includes species such as frogs, toads, salamanders, turtles, lizards, snakes, and tortoises. Although amphibians and reptiles have been known to use a mixture of crossing structure types, most studies suggest riparian amphibians and reptiles tend to prefer small pipes, as well as box or pipe culverts with natural substrates while upland amphibians and reptiles prefer box culverts. Larger crossing structures (bridges) can be modified to accommodate amphibian and reptiles by incorporating smaller tunnels along the sides of the crossing structure.

Opening Cover:

Amphibians and riparian reptiles are prey species and rely on low stature cover for protection from predators. If low stature cover around the structure entrance is absent, these animals may be reluctant to enter. Furthermore, preserving the natural vegetative cover is important for maintaining habitat continuity.

Structure Placement:

Bridges are generally placed at streams; however, for many amphibians and reptiles, movements and migrations are not associated with streams, but between upland and wetland areas.

Travel distance to the bridge can be an important factor in facilitating movement of amphibians/riparian reptiles. Although there is evidence mammals can learn to use bridges and may transfer this knowledge to future generations, this is unlikely for amphibians and reptiles. Smaller structures, such as pipes and culverts, should be used in conjunction with bridged crossings and placed with a frequency that corresponds to the spatial scale over which the targeted species moves.

Funneling/Fencing:

Impenetrable materials to use include galvanized tin, aluminum flashing, plastic, vinyl, concrete, or a very fine mesh. Snakes and tree frogs have been observed climbing vegetation along funneling mechanisms. Therefore, monitoring and removal of vegetation along fences is suggested to ensure passage through the structure.

Fish [\(top\)](#)

To be conducive as passage for use by fish, bridges must:

- Maintain a constant grade along the length of the bridge, and avoid large drops above or below the structure. Alternatively, if a new bridge is proposed in an area where the Department has determined a barrier to fish movement might be desirable, construction options could be explored.
- Accommodate both juvenile and adult fish.
- Maintain water depth through the bridge openings similar to those in the natural stream.
- Minimize turbulence and flow contraction because turbulence inhibits or prevents animal passage.
- Allow upstream fish passage.

Bridges (cont.)

Structure Placement:

Bridge overpass alignment should be similar to that of the natural stream. In-channel deposition and bank scour may lead to stream degradation. Drops greater than 2-4 inches or scour pools will obstruct upstream and downstream fish passage.

Internal Habitat:

Ensure water depths are sufficient to allow passage of fish and other aquatic organisms during all seasons, unless otherwise desired based on coordination with the Department. Construct bridge bottoms with natural stream substrates and design a channel under the bridge to provide fish passage during low-water periods.

Multiple Animal Type Use ([top](#))

Multiple group recommendations

These recommendations are intended to provide the most desirable bridge characteristics for multiple groups of species.

Funneling/Fencing:

Appropriate funneling mechanisms vary widely across groups of animals. To accommodate several species, a fine mesh wire fence or flashing is often applied to the bottom one-third to one-half of a taller fence to prevent both small and large animals from accessing the road right-of-way. Additional measures include combining fencing for large mammals along the road with lipped walls for amphibians and reptiles along the banks for the structure entrance.

Structure Approach:

Vegetation surrounding the approach to the structure is an important consideration when designing for multiple species. While some level of natural vegetation is important to maintain habitat continuity, the type of vegetation can play an important role in bridge passage use. Most small mammals, amphibians, and reptiles prefer low stature cover in the form of vegetation, rocks, and logs to protect them from predators. Medium and large mammals that are prey species (rabbits, deer) may be wary of using structures with extensive vegetation where predators can hide. Eliminating potential predator ambush opportunities, while providing good visibility for medium and large mammal prey species, will encourage use of a bridged crossing.

Structure Design:

While considering the variety of internal habitats preferred by different animal groups, it is not surprising specific design elements for particular species may be contradictory. For example, favorable lighting, temperature, and moisture conditions for amphibians but may be too noisy for some mammals. Structures can be designed to facilitate multiple groups by incorporating design elements preferred by each. For instance, a large bridge underpass designed to facilitate the movement of large mammals could also accommodate small mammals by incorporating low stature vegetation or other naturally occurring substrate, such as tree stumps, hollow logs, or rocks in the interior of the structure. Similarly, a structure could accommodate small mammals, amphibians, and riparian reptiles by maintaining moisture in the bottom of the structure but also providing a dry elevated ledge or animal access shelving. Alternatively, multiple structures in the

Bridges (cont.)

same area could be incorporated to accommodate several groups. Ultimately, there is no simple single approach. A variety of alternatives can and should be explored, with particular attention paid to local threatened and endangered species, and known wildlife and fish migration corridors. A structure that incorporates as many design elements as possible will most likely be the most successful at accommodating wildlife movement.

Post Construction & Monitoring [\(top\)](#)

Following bridge construction, there are several measures that can be taken to ensure continued effectiveness of the bridge and use by fish and wildlife. These include:

- Installation of traffic control measures (animal crossing signs).
- Monitor structures to ensure they are clear of obstructions such as detritus or silt blockages that impede movement.
- Monitor and evaluate effectiveness as a fish and wildlife crossing and make appropriate adjustments if necessary (e.g. Retrofit fencing or other modifications), and coordinate and report findings to fish and wildlife management agencies.
- Evaluate bridge impacts on erosion and riparian areas to ensure habitat integrity.

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